



A System Architectural View of the Smart Electric Power Grid

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Global Smart Energy
November 13, 2009
Monterey, CA

The Smart Grid is the seamless integration of an electric grid, a communications network, and the necessary software and hardware to monitor, control and manage the generation, transmission, distribution, storage and consumption of energy by any customer type.

Moreover, we share a broader vision of the smart grid that encompasses the integration of renewable energy and electric vehicle infrastructure.

Market Drivers for the California Smart Grid 2020

- Legislation on environmental impact, GHG reductions, energy efficiency, RPS targets
- Loan guarantees and tax credits that incentivize (albeit perhaps not optimally in a systems context) the incorporation of new technologies
- Increased energy demand in stationary and transportation sectors due to population growth and continued economic development
- The volatile cost of fossil fuels and attendant ramifications on security
- Geographic distribution of the transmission network
- Consumer-level demand for improved quality of service, reliability and cost-savings

California Energy Policy Targets	Criteria to assess contribution of smart grid technologies in support of the target goals
Climate change – improve the environmental impact of the grid on California (reducing GHG emissions)	How to meet AB32 mandates for reductions of GHG emissions to 1990 levels by 2020, while incentivizing the market for rapid adoption of new and innovative smart grid technologies.
Energy efficiency – increase efficiency of the grid	How to meet cost-effective energy efficiency in electricity and natural gas supply while reducing demand, and supporting legislated initiatives in a technologically sound and viable manner.
Demand response – improve overall grid system operational reliability, availability, sustainability and maintainability	How to mature a power delivery system fully equipped with control and communications that allow integration of distribution automation functions, and allows for the smooth operation of renewable energy sources.
Renewable energy – ability to increase penetration of renewable technologies on the California smart grid	How can the smart grid architecture be designed to enable the integration of renewable energy supplies that meet RPS targets while mitigating the risk of intermittency through large-scale energy storage, distributed storage and smaller-scale DER.
Distribution systems – reduce costs of operations [and maintenance] of the grid	How will C ² structures be implemented at the distribution nodes in a manner that is operationally sustainable, meets consumer-level requirements for quality of service, new end-use applications, and offers good cost-benefit in O&M, security, etc.

Systems Engineering

- **System architecture** includes separate but related viewpoints for describing organizational, functional, physical, informational, and lifecycle aspects of system design.
- An **exploration of alternatives** in a complex design space helps to highlight key design issues, provides a basis for comparing architectures and selecting an architecture, and promotes finding better design solutions for the project.
- A **structured approach** to decomposition within each viewpoint (requirements, functional, physical...) provides an effective means of defining complex systems.
 - Maintaining consistency between corresponding elements in related viewpoints ensures design integrity.

Smart Grid System Tradeoff Space

- The tradeoff space is defined across RD&D, investment and smart grid functionality parameters captured in legislation (i.e. Energy Policy Act of 2005, Energy Independence and Security Act 2007) and addressing diverse parameters
 - Energy consumption, measurement and efficiency
 - Energy supply, including distributed energy resources
 - Energy storage for transportation and stationary sectors
 - Component and systems technologies, including C³
 - Infrastructure (monitoring, storage, transmission, distribution)
 - Environmental impact
 - Economic and regulatory considerations

Smart Grid Integration RD&D Needs

- Enhanced measurement systems
- Response-based real-time control systems
- Advanced communications technologies and architectures (C3)
- Robust state estimation
- Autonomous software
- Real-time load forecasting and generation tools
- Advanced power electronics
- Advanced conductors
- Cost-effective energy storage
- Advanced materials – including their development, modeling, failure analysis
- Hydrogen production and storage systems
- Sensor network data mining and visualization tools
- Cyber-physical and computational modeling techniques
- Breakthroughs in such areas as high-efficiency photovoltaic cells and quantum technologies or nanomaterials.